IMPACT OF LAND SURFACE PARAMETERIZATIONS ON SUMMER-SEASON PREDICTIONS IN THE NCEP CLIMATE FORECAST SYSTEM

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OBJECTIVES

- Assess skills of the NCEP CFS v2 in predicting **SST**, **Precipitation**, and **T2m** anomalies.

- Examine impact of *land surface parameterizations* on summer season predictions with the new CFS.

THE NEW NCEP CFS

The Atmospheric Forecast Model is increased from T62, L28 to T126, L64 (~100 km) resolution and equipped with more advanced physics.

n Forecast Model is
aded from the limited
GFDL MOM3 to the global
MOM4. The horizontal
resolution is increased from
0.33° to 0.25° (10°N- 10°S),
from 1.0° to 0.5° elsewhere
globally.

CFS v2

Introduction of a 3-layer global Sea Ice Model.

The Land Surface Model is upgraded from the 2-layer OSU to the 4-layer Noah LSM.

Fully Coupled Ocean-Land-Atmosphere System, implemented in March, 2011

The CFS IMPLEMENTATION

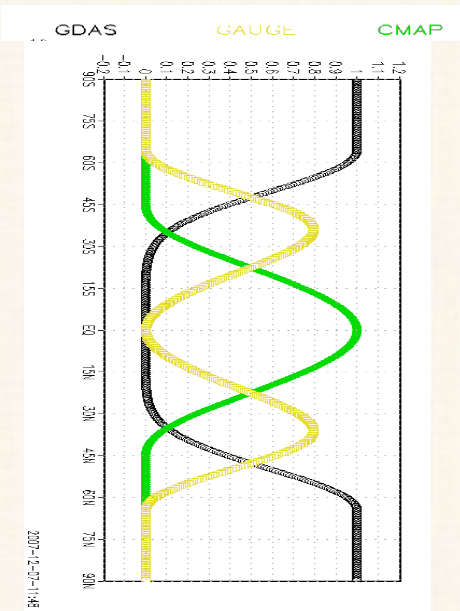
Two essential components

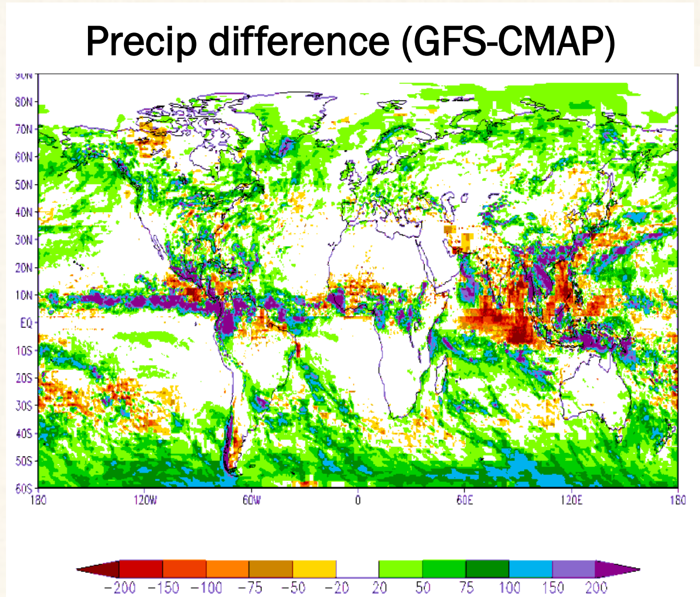
A new Reanalysis of the atmosphere, ocean, sea ice and land (CFS Reanalysis and Reanalysis: CFSRR) over the 32-year period (1979-2010) is required to provide *consistent initial conditions* for:

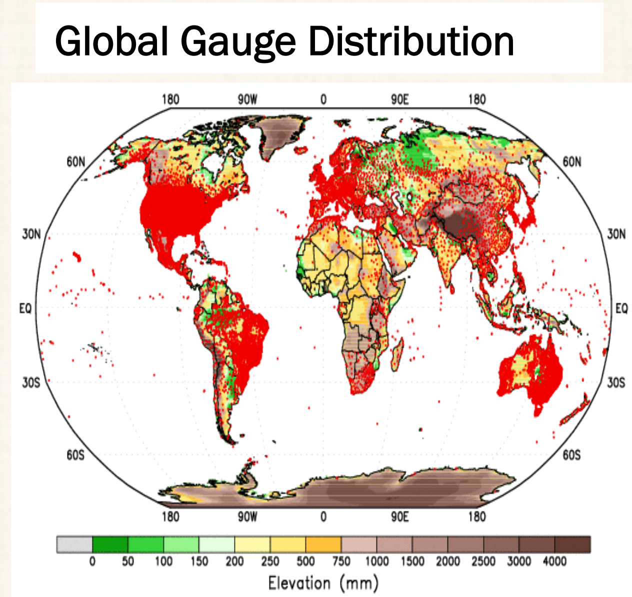
A complete Reforecast of the new CFS (CFS Reanalysis and Reforecast : CFSRR) over the 29-year period (1982-2010), in order to provide stable calibration and skill estimates of the new system, for operational seasonal prediction at NCEP.

Refer to: Saha et. al (including authors in this presentation), 2010:The NCEP Climate Forecast System Reanalysis, *Bull. Amer. Meteor. Soc. 2, 1015-1057*, doi: 10.1175/2010BAMS3001.1.

INITIAL SOIL MOISTURE/TEMPERATURE IN THE CFS RUNS







"Semi-coupled" GLDAS in CFSR:

Near-surface Meteorological forcing from the atmospheric model +

blended precip forcing is used in CFSR with the heavier weights of

CFS/GDAS – high lats; Gauge – mid lats; CMAP – tropics.

Blended forcing to utilize observed precip to reduce the impact of forecast model bias to produce realistic moisture, which is important to summer season predictions

LAND PARAMETERIZATIONS IN THE CFS

- The critical land surface skin temperature T_s depends on ratio of Z_{0m} and Z_{0t} seasonal GVF (with constant LAI), and others.
- Bare soil and vegetation are treated together (one layer), In Noah,

$$\ln \frac{z_{0m}}{z_{0t}} = kC_{zil}\left(\frac{u_* z_{0m}}{\nu}\right)^{0.5}$$

C_{zil}, a tunable parameter (varies in different operational models), is used to compute z_{0t}, z_{0m} is prescribed for all grid cells depending on vegetation types., Von Karman constant *k*=0.4, $\nu = 1.5x10^{-5} m^2 s^{-1}$ is the molecular viscosity.

The physical constraint should be the convergence of turbulent fluxes and T_s to bare soil values (i.e., Z_{0m}, Z_{0t} and displacement height) when the above biomass approaches zero.

MOTIVATION OF THE CFS EXPERIMENTS AND APPROACH

- The Noah LSM has a cold bias of around 10 K in the early afternoon of summer over semiarid regions.
- The previous efforts to reduce the bias were focused on the tunable parameter C_{zil} by adjusting its value or taking as a function of vegetation height h, e.g. , $C_{zil} = 10^{-0.4h}$ (Chen and Zhang, 2009).
- However, there is no vegetation height input to the Noah LSM. The C_{zil} derived from the corresponding vegetation height would lead to an overestimation of T_s , suggesting that the problem can't be fixed by just tuning the parameter and the prescribed Z_{0m} also needs to be adjusted, by explicitly applying the physical constraint. Following Zeng and Wang (2007),

$$\ln(z_{om,e}) = (1 - GVF_{max})^2 \ln(z_{og}) + [1 - (1 - GVF_{max})^2] \ln(z_{om})$$

the bare soil roughness length z_{0g} is taken as 0.01, effective roughness length for momentum is $Z_{0m,e}$, the maximum Green Fractional Cover is $GVF_{\max}$, and the prescribed roughness for momentum is z_{0m} .

MOTIVATION OF THE CFS EXPERIMENTS AND APPROACH (CONT'D)

To ensure the continuity of the fluxes, the ratio needs to be rewritten as:

$$\ln \frac{z_{0m,e}}{z_{0t}} = (1 - GVF)^2 C_{zil} k (\frac{u_* z_{0g}}{\nu})^{0.5}$$

Where GVF is the seasonal Green Vegetation Fraction, the C_{zil} is changed to 0.8 based on the comparison between Noah off-line simulation and observations.

Pilot experiments with the NCEP GFS shows an improvement with Medium Range Forecasts.

<u>How these changes impact on CFS seasonal predictions</u> ?

References: Chen, F., and Y. Zhang, 2009: On the coupling strength between the land surface and the atmosphere: From viewpoint of surface exchange coefficients. *Geophys. Res. Lett.*, 36, L10404, doi:10.1029/2009GL037980.

Zeng, X., and Z. Wang, 2007: Consistent Parameterization of Roughness Length and Displacement Height for Sparse and Dense Canopies in Land Models. *J. Hydrometeor.*, 8, 730-737, DOI: 10.1175/JHM607.1.

EXPERIMENTAL CFS DESIGN

<u>Control</u> *vs*. <u>Experimental</u>

- Use 4 ensemble members with Initial Conditions from *May 01@00,06,12,18Z* over
- Selected 9 years:82,86,87,88,91,96,99,00,07 (MJJ, Ňino 3.4) that include warm, cold and neutral ENSO indices
- On T126 Gaussian grid with the new CFS/Noah and CFSR initial land states for 2 months of predictions.

VERIFICATION DATASETS AND METHOD

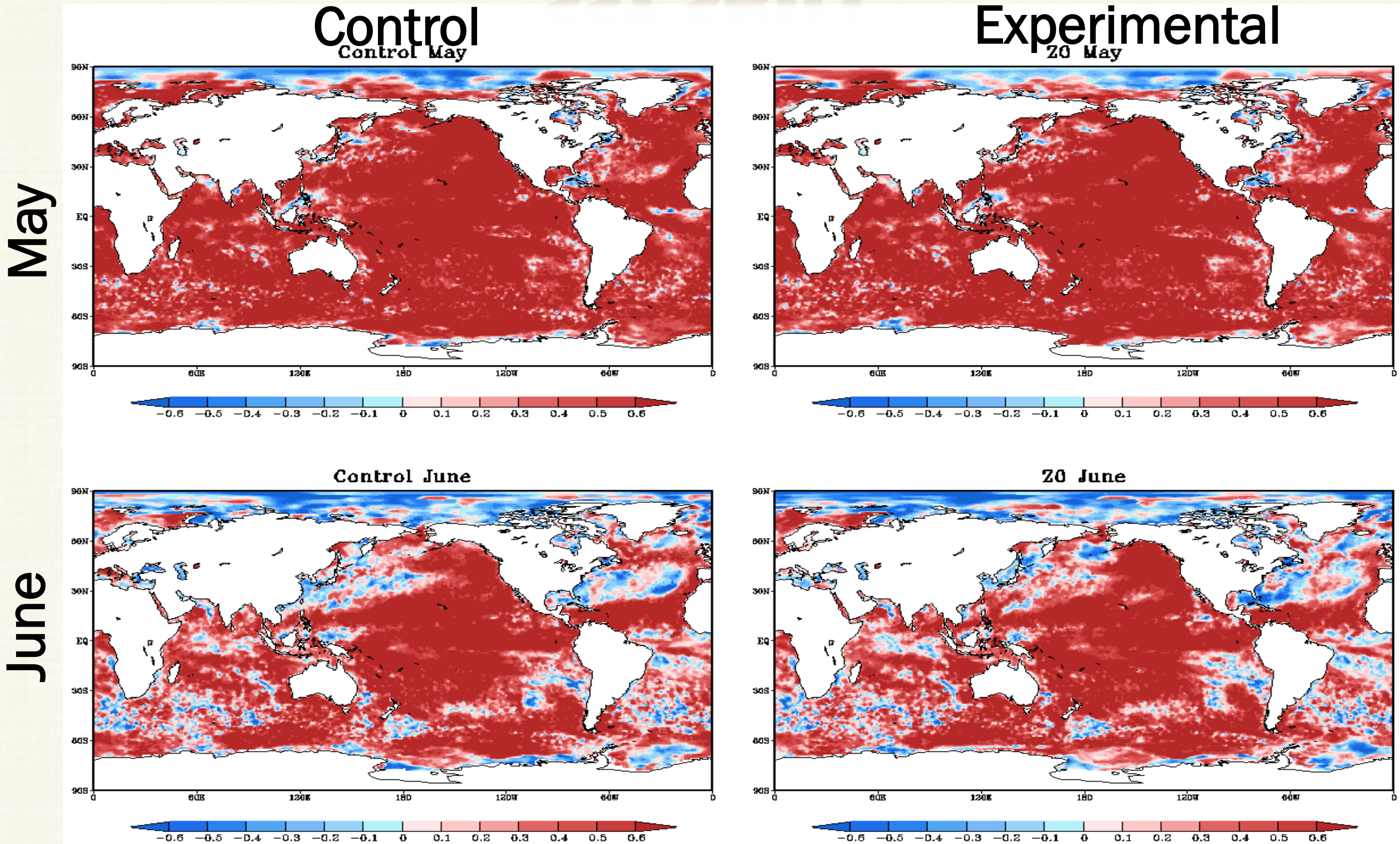
- GPCP Pentad Precipitation Analysis for precipitation (Xie et al.,2003).
- GHCN/CAMS (land) T2m Analysis for T2m (Fan and Van den Dool, 2008).
- NOAA Optimum Interpolation (OI) SST for SST (Reynolds, 1988).
- Anomaly correlation is used as a measure of the skills for months of May and June.

References:

Fan, Y., and H. van den Dool (2008), A global monthly land surface air temperature analysis for 1948-present, *J. Geophys. Res.*, 113, D01103, doi: 10.1029/2007JD008470.

Xie, P. and Coauthors, 2003: GPCP Pentad Precipitation Analyses: An Experimental Dataset Based on Gauge Observations and Satellite Estimates. *J. Climate*, **16**, 2197–2214. doi: 10.1175/2769.1.

SST SKILL

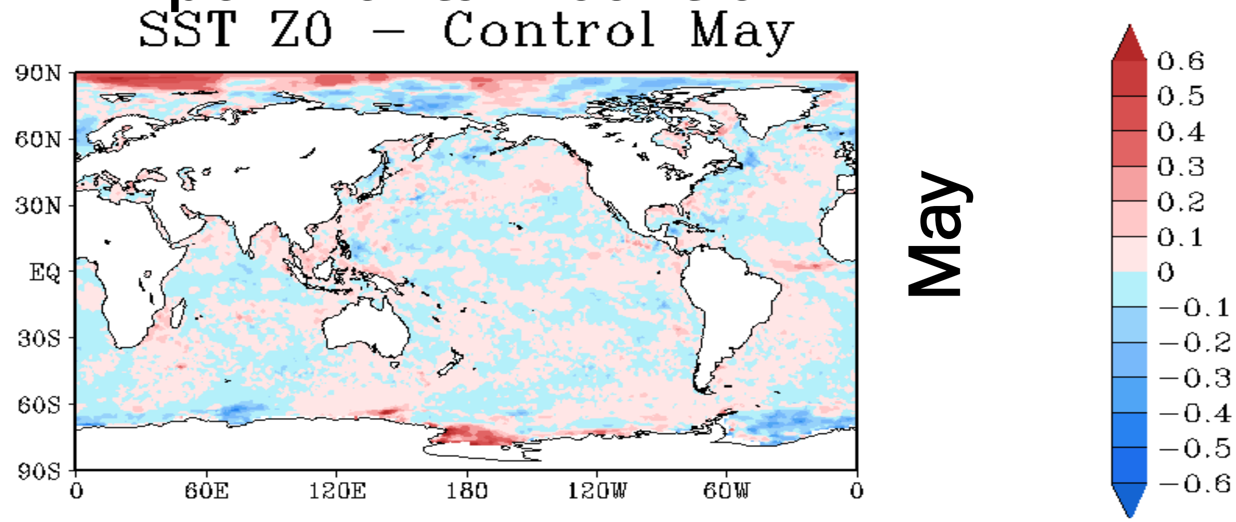


High skill globally for lead 0, decreases with lead 1 (mid-latitude), still maintains good performance over most of the globe, especially over the Nino regions

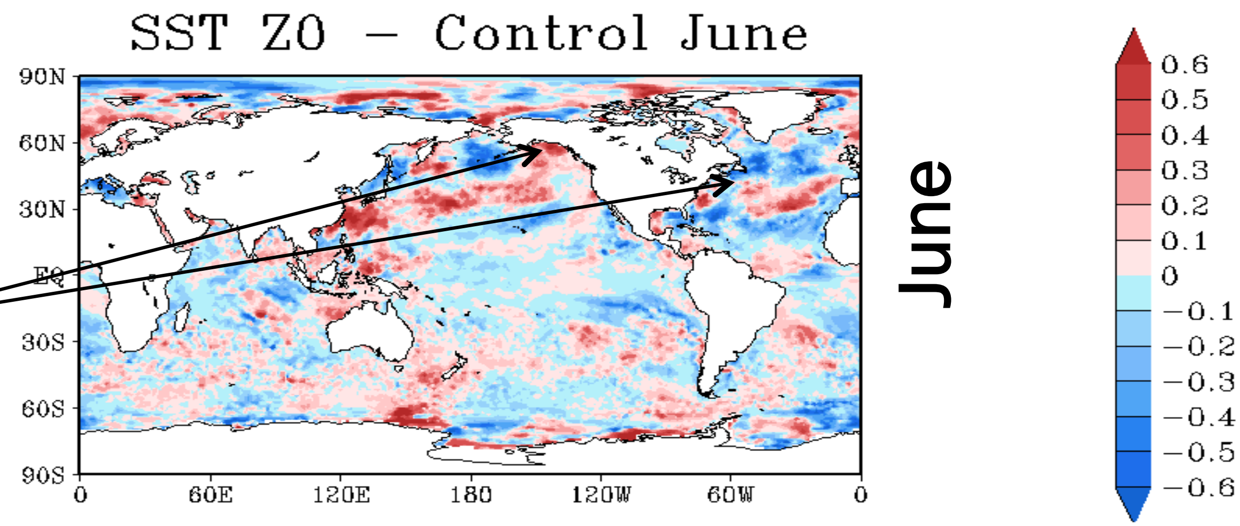
SST SKILL DIFFERENCE

Experimental - control

No surprise, small difference in lead 0, initial ocean conditions is the main control and land impact is very small



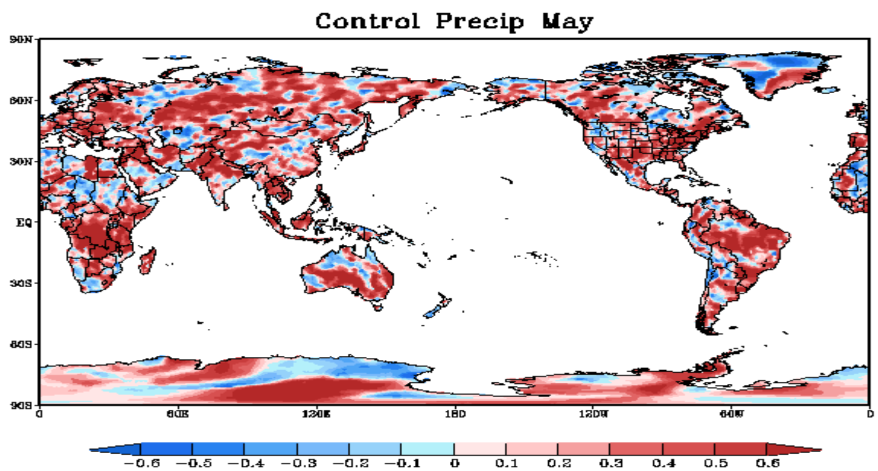
Slightly better over the Pacific mid-latitudes and equatorial Atlantic ocean, still small over the tropics

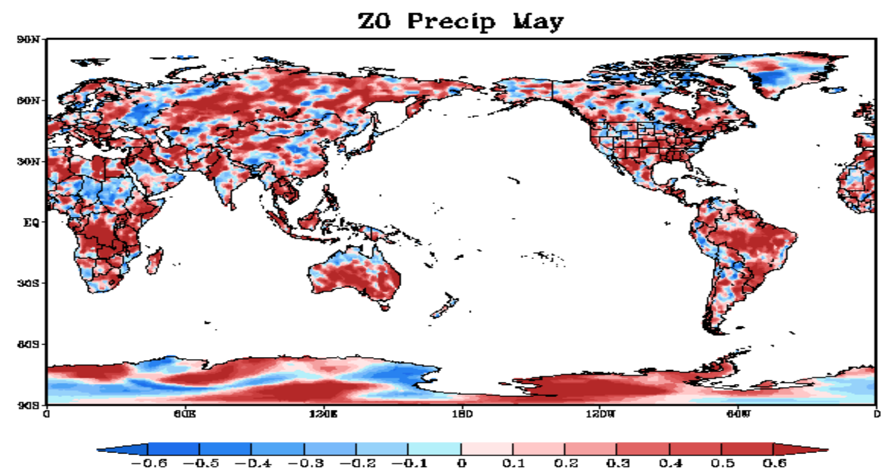


PRECIPITATION SKILL

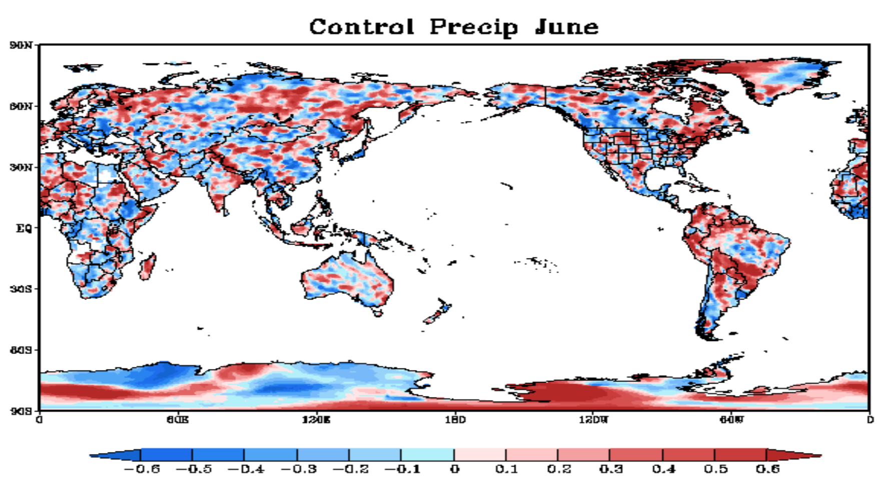
Control | Experimental

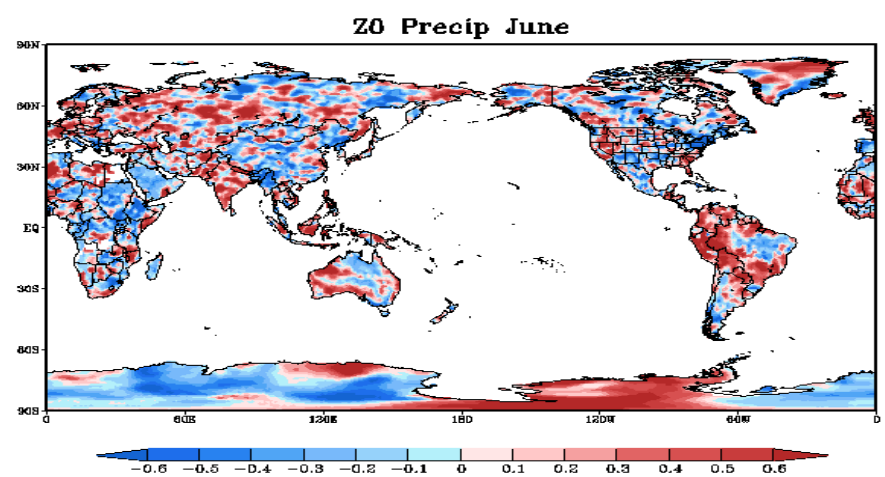
May





June



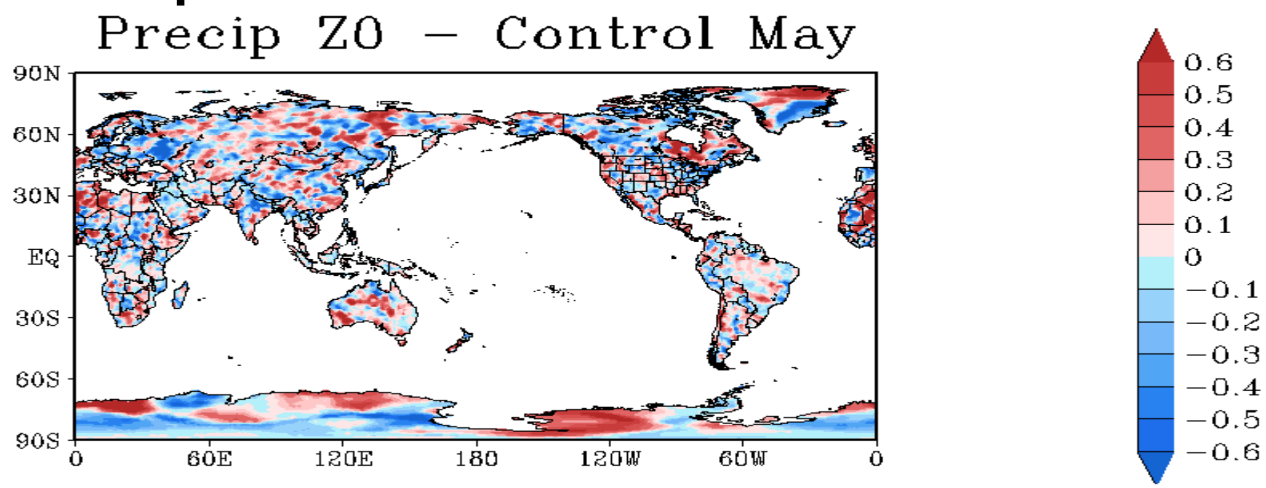


Higher skill and similar patterns in lead 0, decreases substantially in lead 1.
As expected, the decrease is relatively small in the Southern Hemisphere (cold)

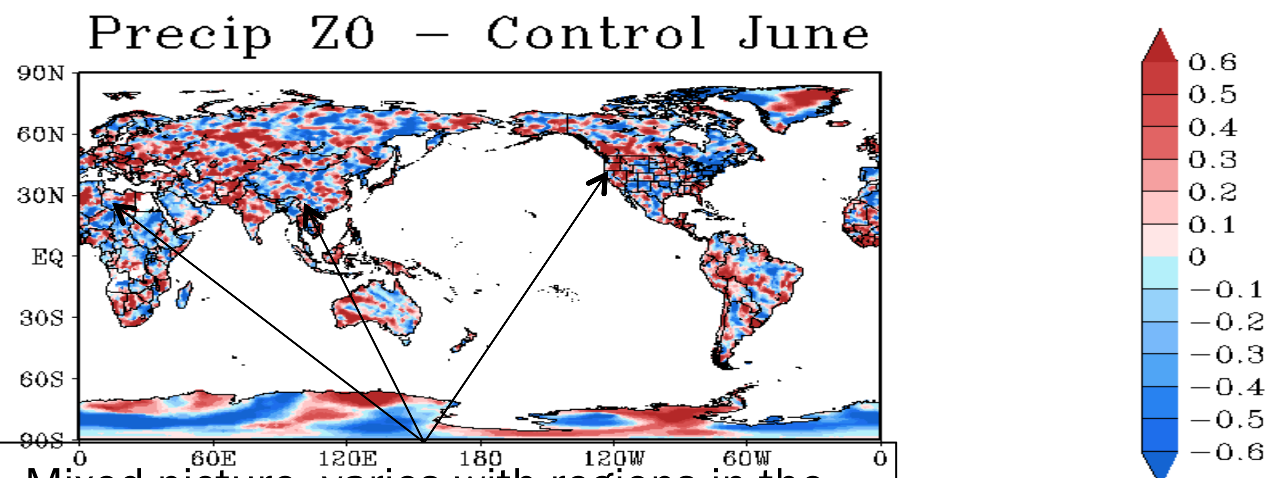
PRECIP SKILL DIFFERENCE

Experimental - control

May



June



Mixed picture, varies with regions in the N.H., small changes in the patterns with both leads in the S.H.

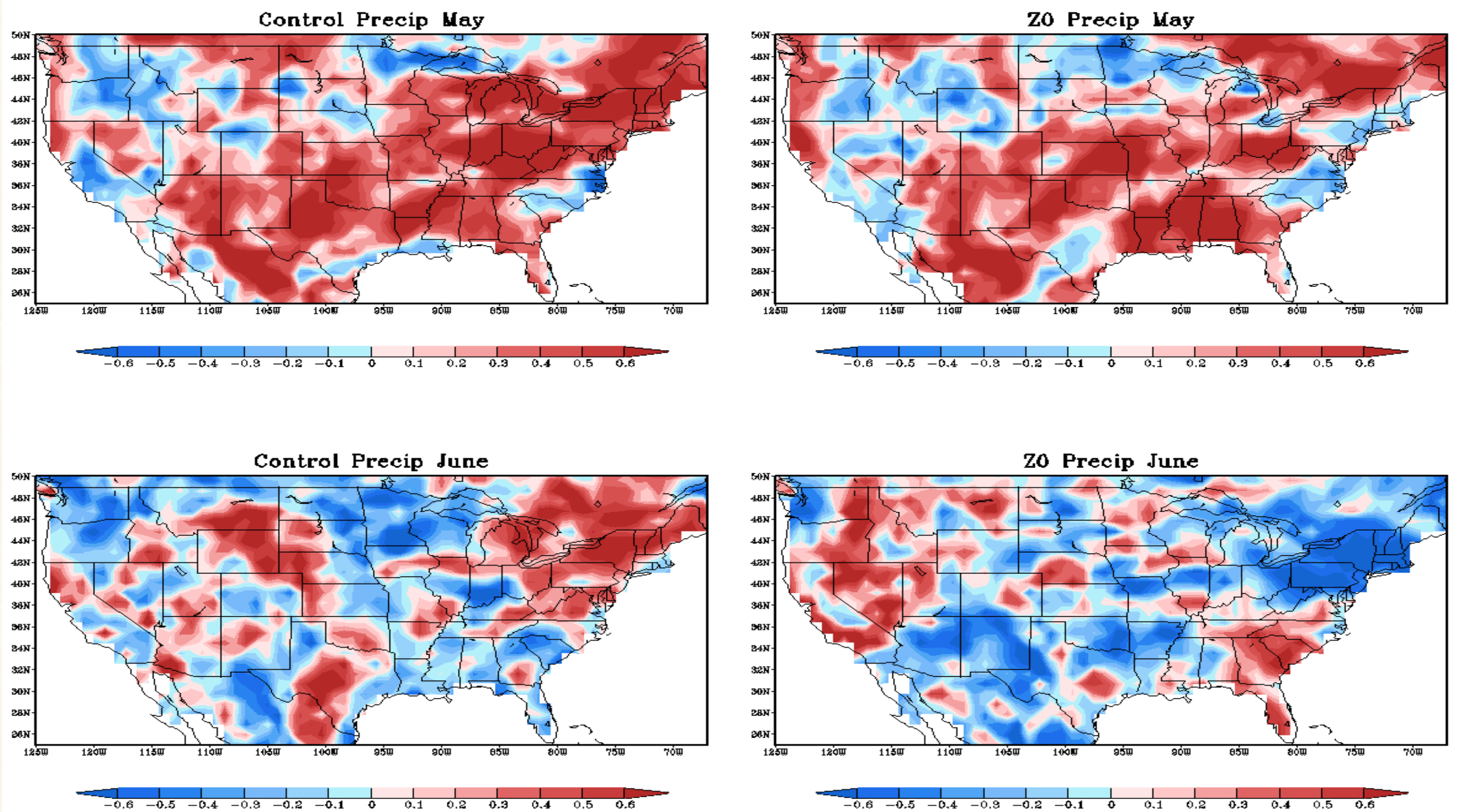
PRECIPITATION SKILL

CONUS

Control | Experimental

May

June



Patterns similar to the global, no big difference in lead 0. Skill gain/loss varies with different climate regimes in lead 1

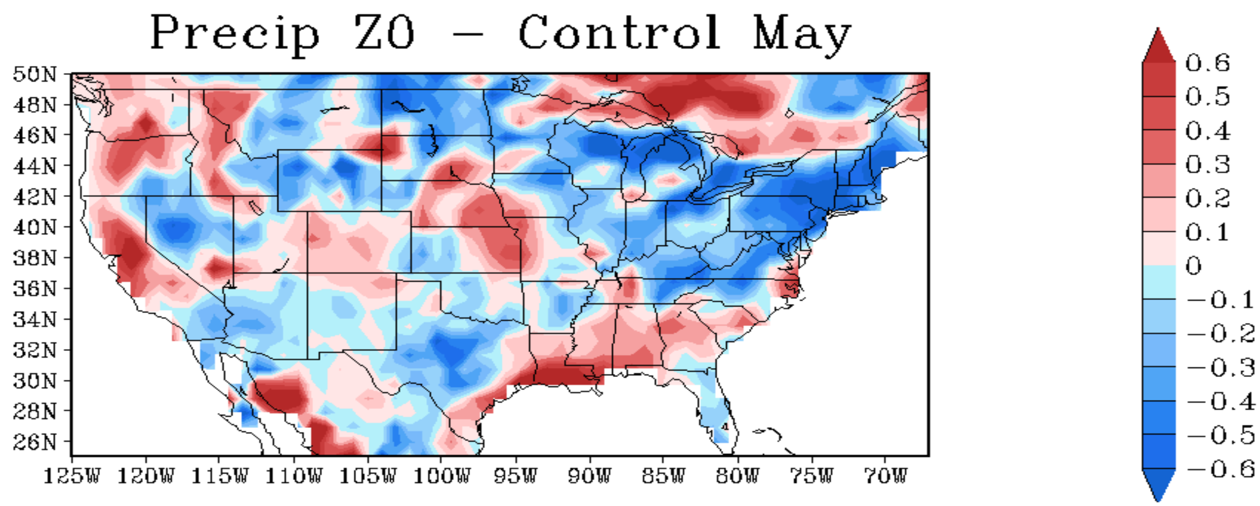
PRECIP SKILL DIFFERENCE

Experimental - control

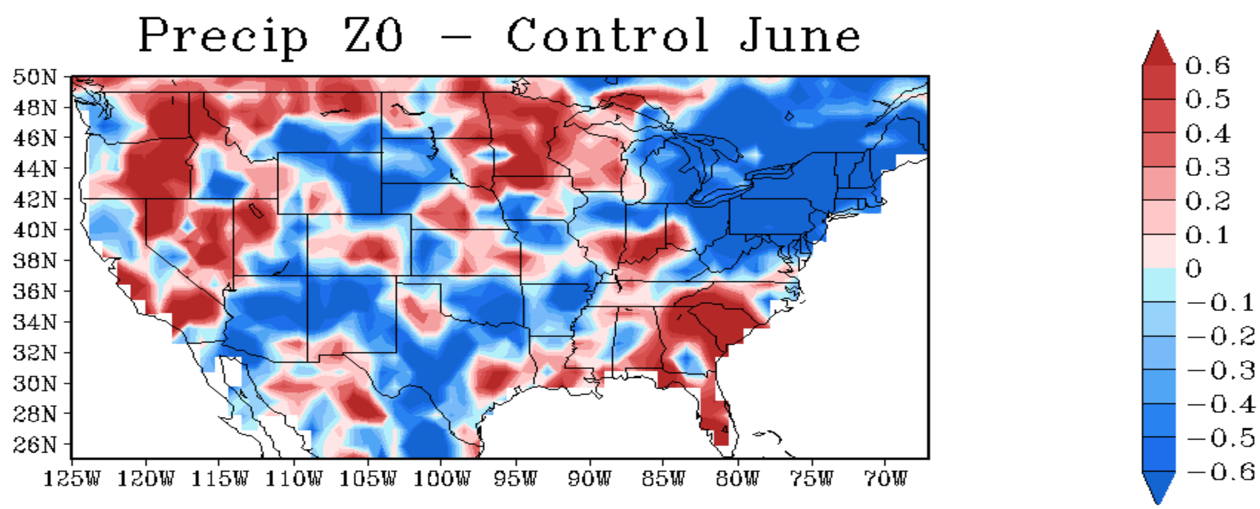
CONUS

Better over the northwest Pacific states in lead 1, worse over the east (New England region) in both leads

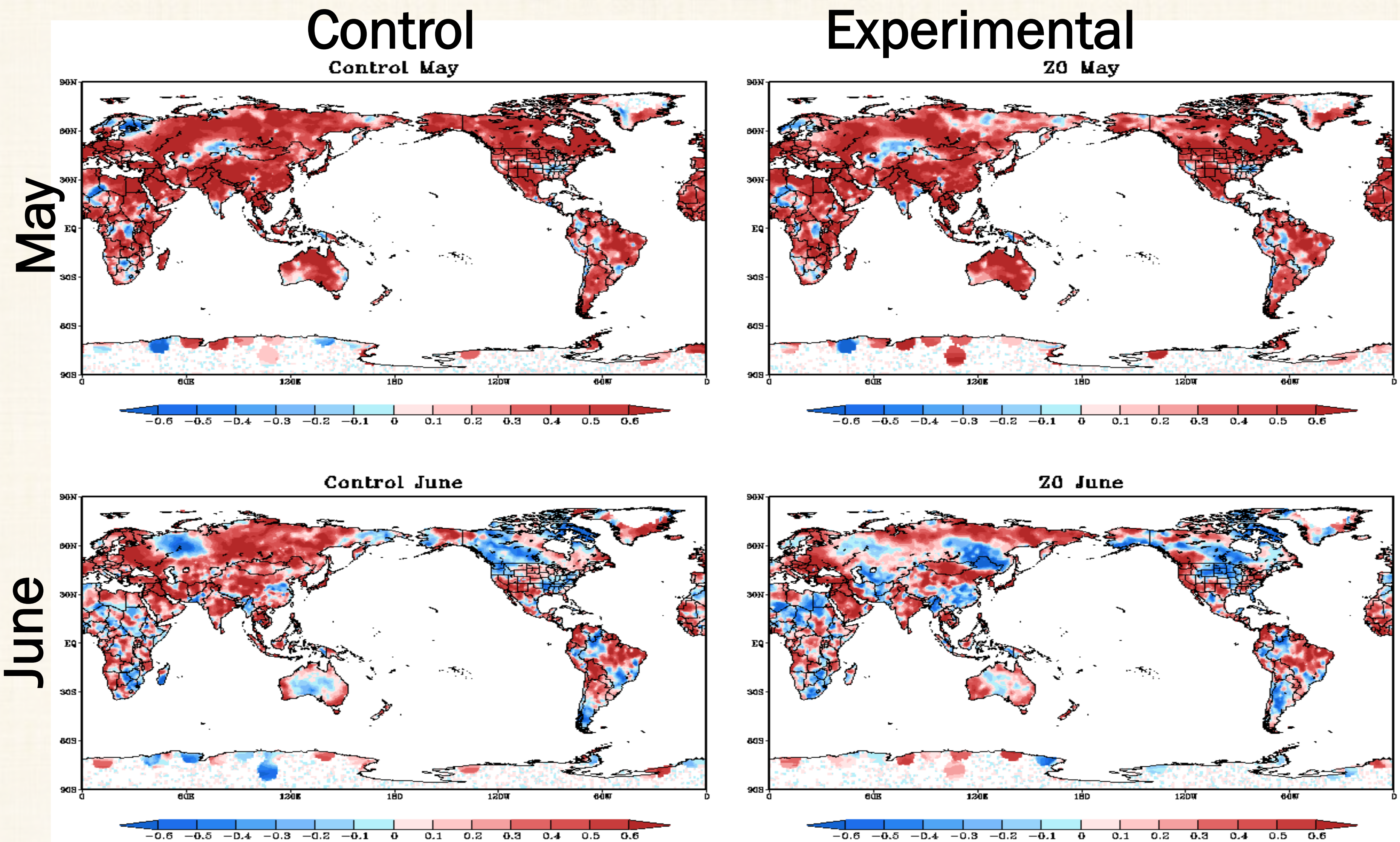
May



June



T2M SKILL

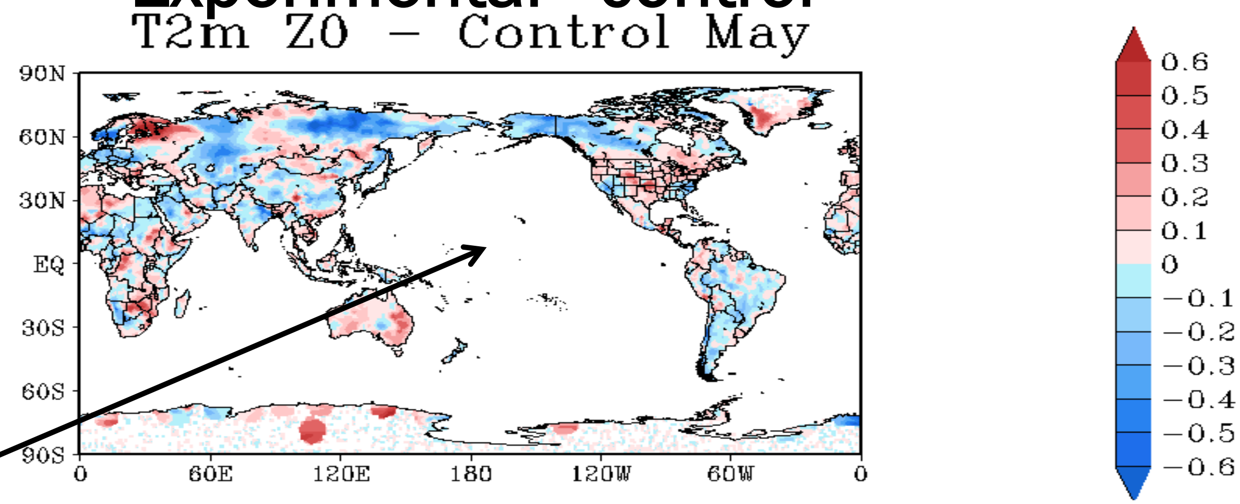


Higher skill than precipitation and close to each other in lead 0 decreases substantially in lead 1 over both hemispheres

T2M SKILL DIFFERENCE

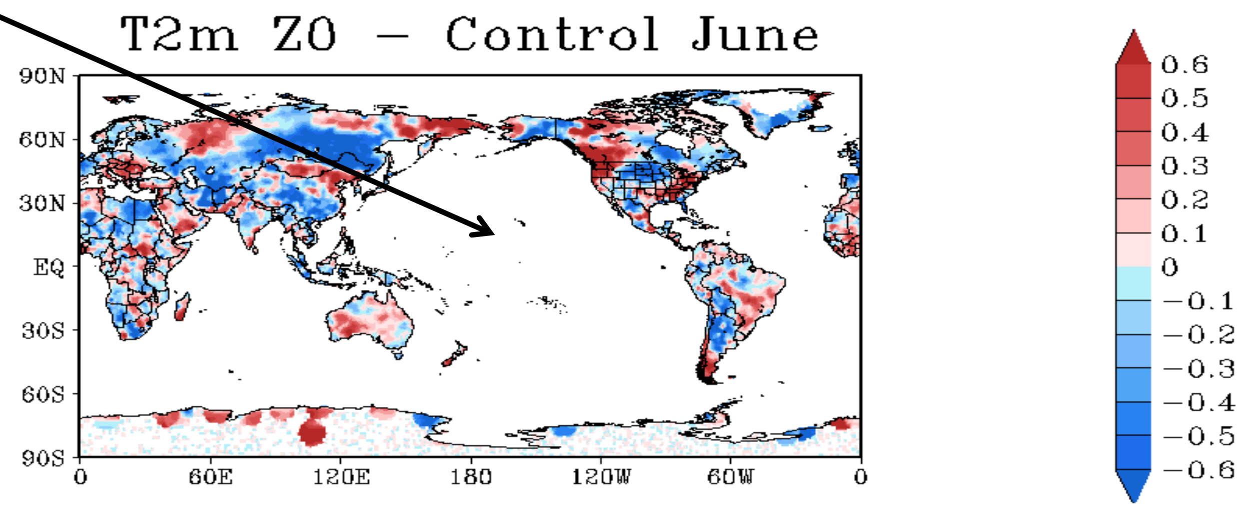
Experimental - control

May



Main difference in Mid to high latitudes

June



Similar to the global skill, the difference varies with regions

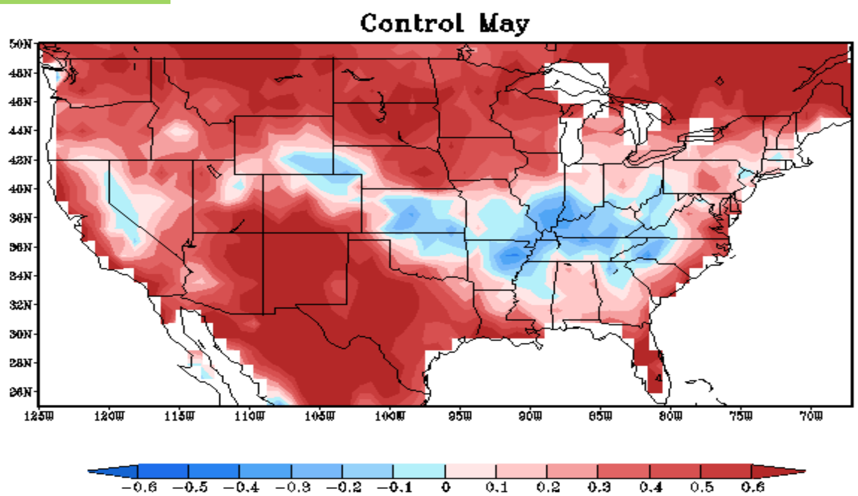
T2M SKILL

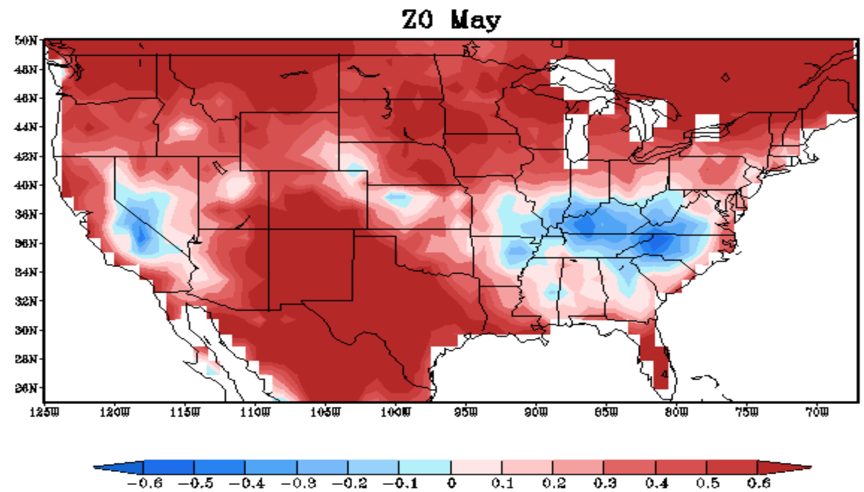
CONUS

Control

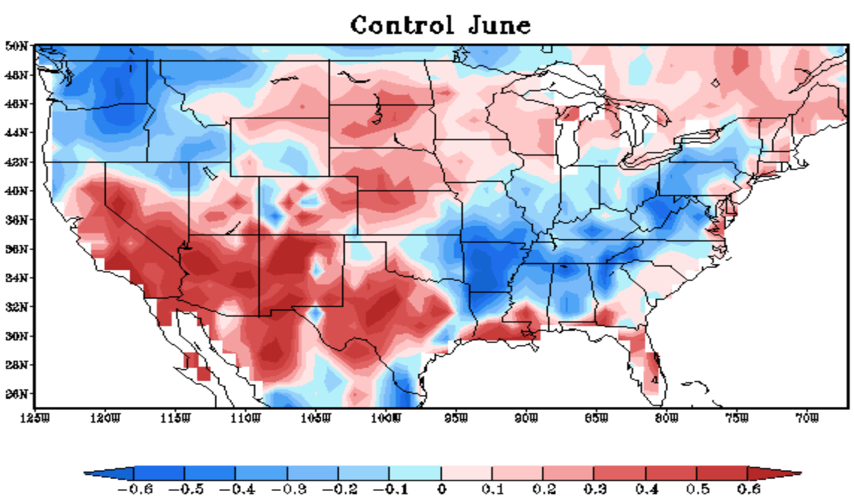
Experimental (ZO)

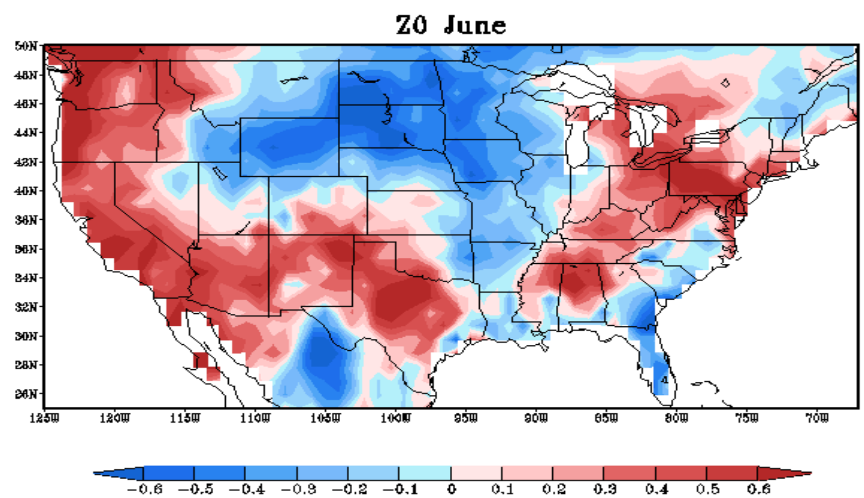
May





June





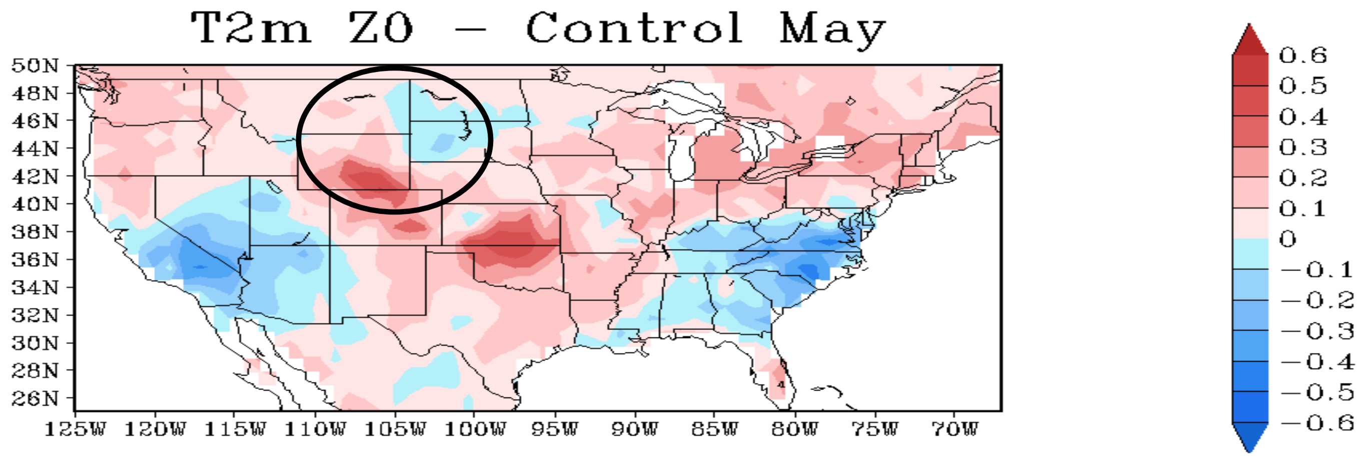
Higher skill in lead 0, decreases substantially in lead 1,

T2M SKILL DIFFERENCE

Experimental - control

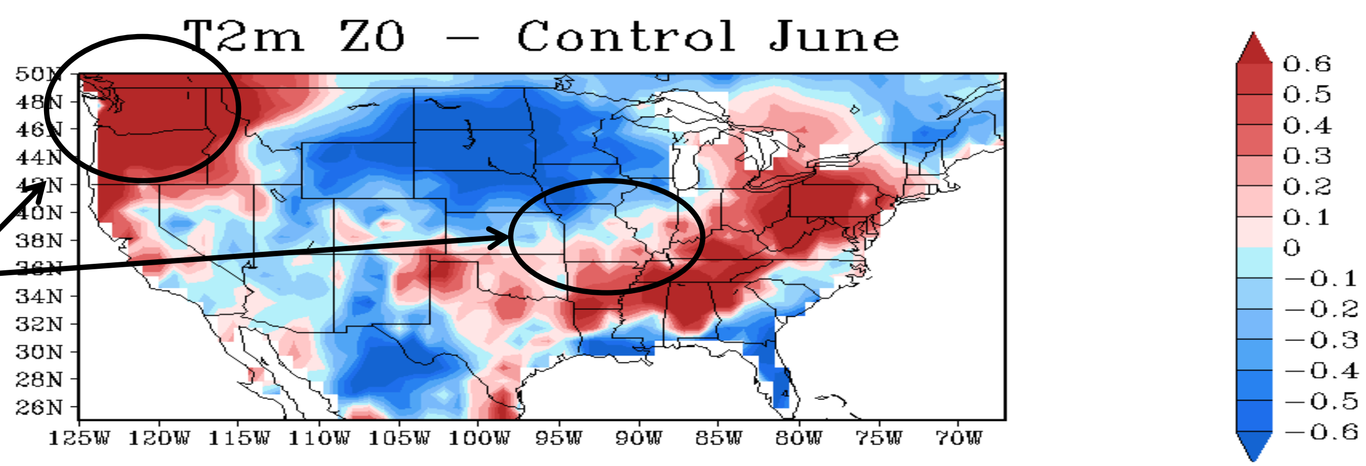
CONUS

May



June

May come from better ocean



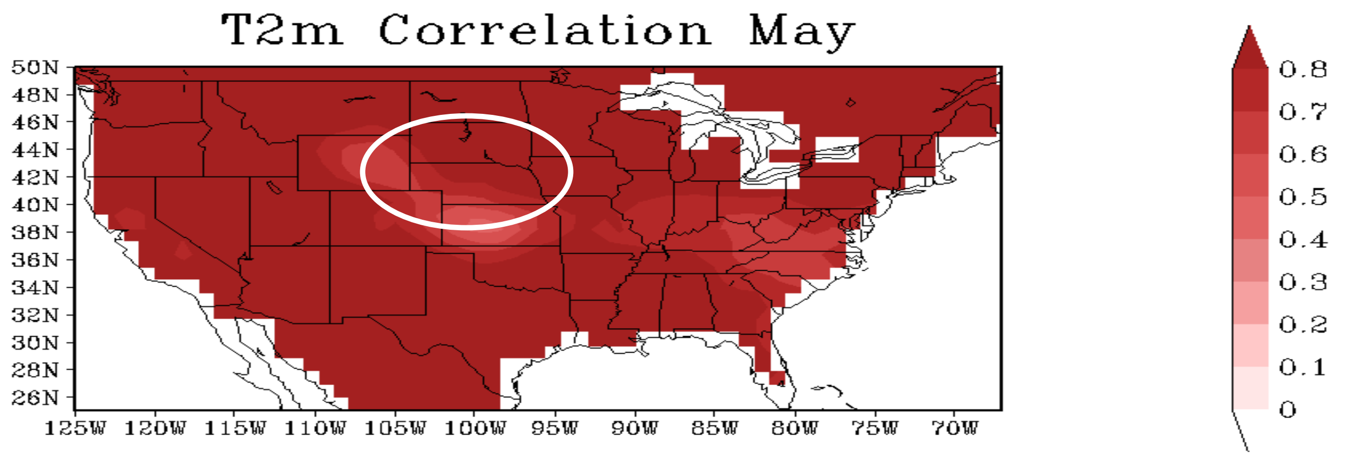
Better over most of the CoNUS, especially over central great plains in lead 0. Higher skill over the Northwest Pacific and mid-Atlantic regions in lead 1

PREDICTED T2M CORRELATION

BETWEEN THE TWO

CONUS

May



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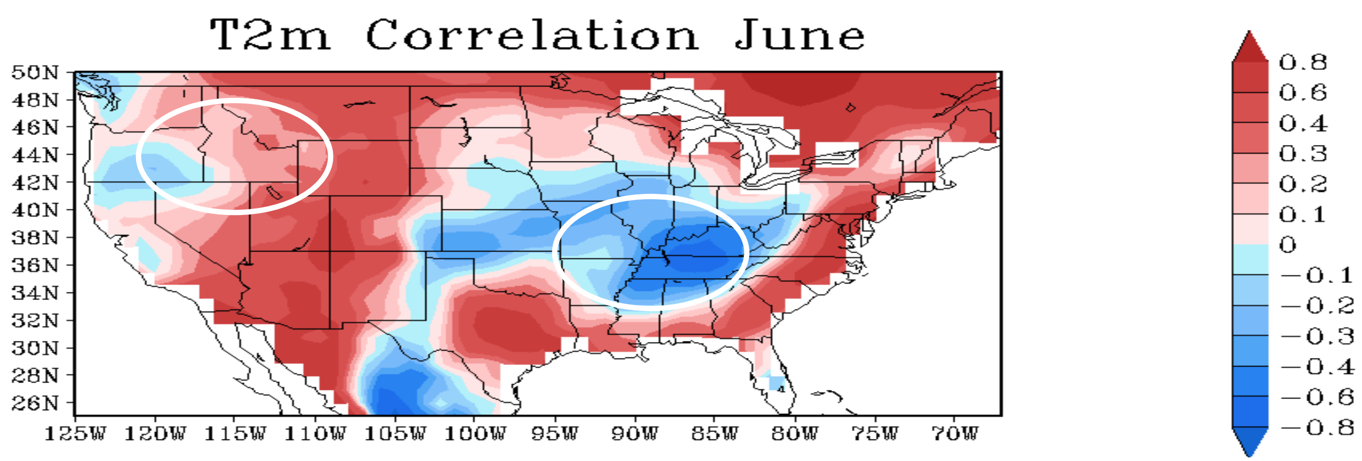

The skill gain mainly comes from the disagreements between the two configurations

SUMMARY

- The new formulations generally lead to a better skill in predicting T2m over the CONUS in the first month and the skill gain/loss varies with different climate regimes for the second month globally.

- The changes made to the roughness lengths have a relatively small impact on the precipitation skill, suggesting that the ocean and atmosphere are still the dominant controls over warm season precipitation for relatively short leads.

- The impact is also affected by the land-atmosphere coupling strength. The differences mainly show up in the second month due to the coupled nature. An examination of the atmospheric circulation could be very useful.

- A careful treatment to land surface parameterization is important to mid-range/seasonal predictions.

- More years may be needed to confirm the patterns.